

TURBOCHARGER MATCHING FOR TWO CYLINDER CONSTANT SPEED DIESEL ENGINE WITH UNEVEN FIRING ORDER

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ABSTRACT

The major challenge that is faced by most of the engine manufacturers nowadays is to meet the stringent emission norms with least modification in the engine design. In achieving the emission norms simplicity of the design has to be maintained as far as possible by optimizing the available emission control techniques. This project deals with such optimal technique with reduced cost to meet CPCB II in minimum time with minimum design changes.

In this work, Turbocharger matching is done for an uneven firing order Engine that involves the selection of compressor and turbine based on the airflow requirements to meet the required performance and emission. The major challenge is to match the turbocharger for uneven firing order engine where the exhaust flow rate will have pulsation effect. In spite of variations in the exhaust flow, Airflow variation from Turbocharger is kept within 10 kg/h.

KEYWORDS: Turbocharger, Mapping, CPCB II & Uneven Firing

Received: May 30, 2018; **Accepted:** Jun 18, 2018; **Published:** Jun 28, 2018; **Paper Id.:** IJMPERDAUG201812

INTRODUCTION

The significant test that is looked at by the greater part of the engine makers these days is to meet the stringent emission standards with minimum change in the engine design. In accomplishing the outflow standards effortlessness of the plan must be kept up beyond what many would consider possible by enhancing the accessible discharge control systems. In accomplishing the outflow standards effortlessness of the plan must be kept up beyond what many would consider possible by improving the accessible emission control procedures.

Turbocharger mapping is a tedious procedure and there is a requirement for an orderly procedure that can be executed naturally. A engine and test cell control structure that can be utilized to robotize and screen the estimations by controlling the framework to the coveted working focuses is likewise proposed. In tests, utilized for developing the compressor speed lines, it is for all intents and purposes difficult to control the turbocharger to the correct redressed speed that is hypothesized by the speed line.

Turbocharger matching involves the selection of compressor and turbine based on the airflow requirements to meet the required performance and the emission.

The main challenge is to match the turbocharger for uneven firing order engine where the exhaust flow rate will have which will further affect pulsation effect the air flow to fluctuate. In this project, our aim is to provide the required with max. Fluctuation of 10kg/hr.

EXPERIMENTAL SETUP

A genuine overwhelming obligation diesel engine, type-h2 with ostensible power 30 kW is utilized as a part of the test ponder. The exploratory setup incorporates estimating instrumentation used to get the engine execution. The detail of this engine is a two– barrel, in line, water cooled, of 106 and 110 mm bore and stroke, individually, with the evaluated yield is 30 KW at 1500 rpm. The engine was joined in revise arrangement with the dynamometer; this helps enduring running and takes out the vibration. Outer stacking is completed by a Froude water powered dynamometer (type D. P .Y). A cardan shaft with two general joints and of an outline which counteracts spinning was given to interface the dynamometer to the engine. The dynamometer is utilized to gauge the engine torque with a mechanical scale. This dynamometer is guaranteed to be exact to inside $\pm 0.025\%$ of ostensible rating. All engine liquid temperatures are checked to utilize K-type thermocouples. The engine has arrangements for differing the fuel infusion timing. High exactness, high determination, high weight territory up to 6000 psig and Low-run flow meter (FTB500 Series) was utilized for deciding the fuel utilization of the engine amid tests. Weight drop as per whole stream meter is utilized to quantify the air conveyed to the engine. This opening plate is fixed before gulf of the compressor with long separation to guarantee the relentless stream of air. Engine speed (rpm) was estimated by toothed rigging and attractive get mix introduced on the engine yield shaft. Be that as it may, the turbocharger speed needs to develop unique circuit comprise of sender and recipient to account the pole pivot. Engine coolant temperature was controlled by warm exchanger tower framework which was intended to thermostatically set and hold a predefined coolant outlet temperature. A test reassures contain the dynamometer controls alongside customary gages for showing engine oil weight, engine speed, water weight too and out the dynamometer, furthermore, the temperatures of delta and outlet water of the engine and the dynamometer, and fumes gases temperatures. Furthermore, the weight and temperature esteem in the most significant areas along the admission and fumes framework, and in addition of high recurrence weight information at similar areas are identified. Likewise, the in barrel high weight sensor (ICP-Model 113B22-up to 350 Pa) is fitted into the engine cylinder to measure the pressure in the cylinder.

DATA ACQUISITION SYSTEM

The signs from the weight transducers, optical sensors and thermocouples, engine speed and wrench edge of pivot sensors were digitized and recorded in PC with the assistance of Lab View programming for later investigation utilizing an information procurement card NI display M arrangement multifunction DAQ for USB - 16 Bit, 250 KS/s, up to 80 simple information. This product is planned, extraordinarily, to incorporate the information from all estimating gadgets and sensors and present it in PC window. The utilized programming bundle has been created in visual essential to mechanize the estimating and revealing methods. Estimating the wrench edge hint of the weight inside the engine chamber is for the most part, a critical target. The program might be utilized for the concurrent estimations up to 8 differential signs. Likewise, the product is intended to figure another parameter, for example, in-barrel temperature, fuel consumption rate and warmth discharge rate with the help of the estimating information.

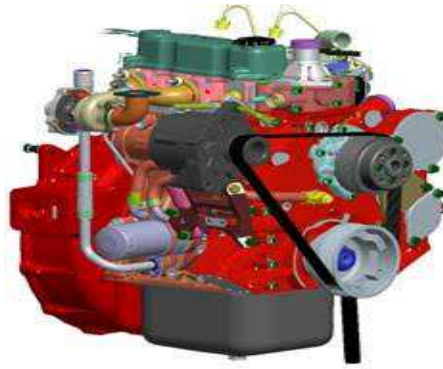


Figure 1: Outline of H2 Engine

Table 1: Specification of the Engine

Engine	2cyl. Inline 1.9L TCIC Engine
Bore	106
Stroke	110
Displacement	1.9L
Power rating	30kw@1500rpm
Application	30kVA Genset engine
FIE	Mechanical inline pump
Firing order	1-2(0°-540°)
No. of valves/cylinder	2valves

RESULTS AND DISCUSSIONS

Obviously a turbo machine is not preferably suited to work in conjunction with a responding machine, consequently, the blend diesel engine and turbocharger must be arranged mind. Coordinating of the right turbocharger to a diesel engine is of incredible significance and is crucial for the fruitful activity of a turbocharged diesel engine.

Three different types of compressors 1570, 1672, 1367 and two turbines KP35 and TR43 were considered for this study.

Table 2: Compressor Mapping for 1570

Input									
Speed rpm	Torque Nm	Power kW	SFC g/kWh	Pressure Drop across Filter in mbar	T1 °C	T3 °C	P4 mbar	Pressure Drop across CAC mbar	AFR
1500	190.0	29.8	240	30	25	600	25	50	26
1500	142.5	22.4	230	22	25	560	20	40	28
1500	95.0	14.9	270	16	25	520	15	25	32
1500	47.5	7.5	295	8	25	490	10	15	40
1500	19.0	3.0	320	2	25	450	10	5	75

The compressor mapping is carried with the input data as shown in table. The values of Airflow, Fuel flow, P1, P2, T2, T2' were calculated and is plotted in the table. And these values are plotted in the Compressor map as shown in figure 2. This procedure repeated for the compressors 1672, and 1367.

Table 3: Compressor Value 1570

1570 Compressor											
Fuel Flow kg/h	Mass Airflow kg/h	Volume Flow Rate of Air m ³ /s	P1 bar	Compressor Efficiency Initial Assumption	P2/P1	P2 bar	P2' bar	T2 K	T2'' K	Me kg/h	Compressor Power kW
7.2	186.1	0.04559	0.97000	74%	1.9	1.843	1.793	358	379	193.2984	4.21
5.1	144.1	0.03500	0.97800	70%	1.7	1.6626	1.6226	347	368	149.2246	2.80
4.0	128.9	0.03111	0.98400	68%	1.6	1.5744	1.5494	341	361	132.8927	2.27
2.2	88.0	0.02107	0.99200	62%	1.4	1.3888	1.3738	328	347	90.19846	1.19
1.0	71.6	0.01704	0.99800	60%	1.3	1.2974	1.2924	321	337	72.54656	0.77

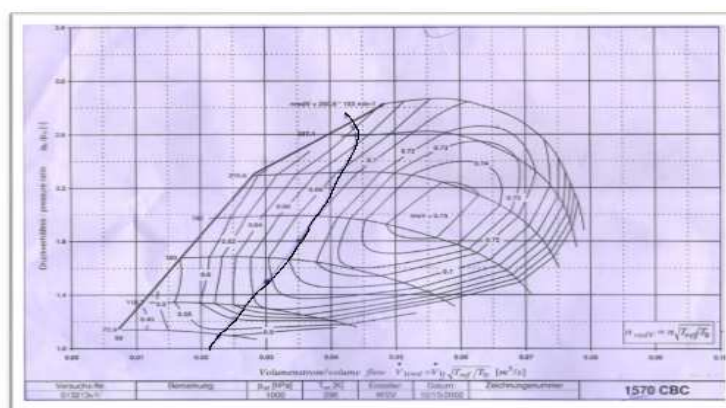


Figure 2: Compressor Map

Table 4: Compressor Mapping for 1672

Input									
Speed rpm	Torque Nm	Power kW	SFC g/kWh	Pressure Drop across Filter in mbar	T1 °C	T3 °C	P4 mbar	Pressure Drop across CAC mbar	AFR
1500	190.0	29.8	240	30	25	600	25	50	26
1500	142.5	22.4	230	22	25	560	20	40	28
1500	95.0	14.9	270	16	25	520	15	25	32
1500	47.5	7.5	295	8	25	490	10	15	40
1500	19.0	3.0	320	2	25	450	10	5	75

Table 5: Compressor Value for 1672

1672 Compressor											
Fuel Flow kg/h	Mass Airflow kg/h	Volume Flow Rate of Air m ³ /s	P1 bar	Compressor Efficiency Initial Assumption	P2/P1	P2 bar	P2' bar	T2 K	T2'' K	Me kg/h	Compressor Power kW
7.2	186.1	0.04559	0.97000	70%	1.6	1.552	1.502	341	359	193.2984	3.18
5.1	144.1	0.03500	0.97800	68%	1.5	1.467	1.427	335	352	149.2246	2.16
4.0	128.9	0.03111	0.98400	65%	1.4	1.3776	1.3526	328	344	132.8927	1.66
2.2	88.0	0.02107	0.99200	60%	1.2	1.1904	1.1754	314	325	90.19846	0.65
1.0	71.6	0.01704	0.99800	60%	1.2	1.1976	1.1926	314	325	72.54656	0.53

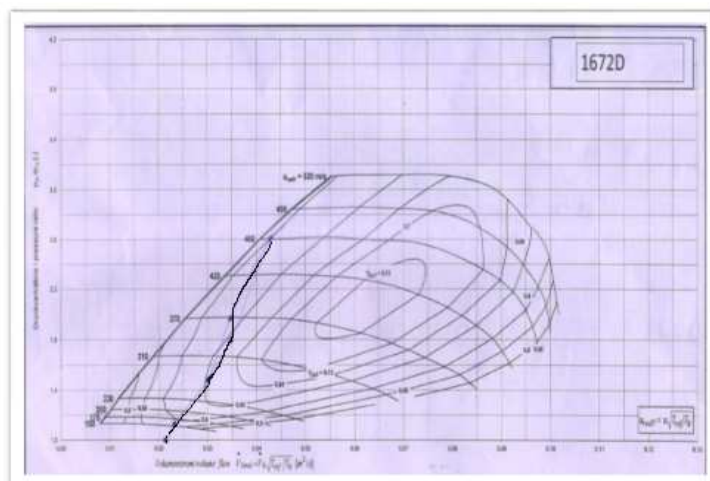


Figure 3: Compressor Map

Table 6: Compressor Mapping for 1367

Input									
Speed rpm	Torque Nm	Power kW	SFC g/kWh	Pressure Drop across Filter in mbar	T1 °C	T3 °C	P4 mbar	Pressure Drop across CAC mbar	AFR
1500	190.0	29.8	240	30	25	600	25	50	26
1500	142.5	22.4	230	22	25	560	20	40	28
1500	95.0	14.9	270	16	25	520	15	25	32
1500	47.5	7.5	295	8	25	490	10	15	40
1500	19.0	3.0	320	2	25	450	10	5	75

Table 7: Compressor Value 1367

1367 Compressor											
Fuel Flow kg/h	Mass Airflow kg/h	Volume Flow Rate of Air m3/s	P1 bar	Compressor Efficiency Initial Assumption	P2/P1	P2 bar	P2' bar	T2 K	T2" K	Me kg/h	Compresso Power kW
7.2	186.1	0.04559	0.97000	72%	2.2	2.134	2.084	373	403	193.2984	5.43
5.1	144.1	0.03500	0.97800	74%	1.8	1.7604	1.7204	352	372	149.2246	2.96
4.0	128.9	0.03111	0.98400	72%	1.62	1.59408	1.56908	342	359	132.8927	2.20
2.2	88.0	0.02107	0.99200	68%	1.3	1.2896	1.2746	321	332	90.19846	0.84
1.0	71.6	0.01704	0.99800	64%	1.2	1.1976	1.1926	314	323	72.54656	0.50

Compressor Map

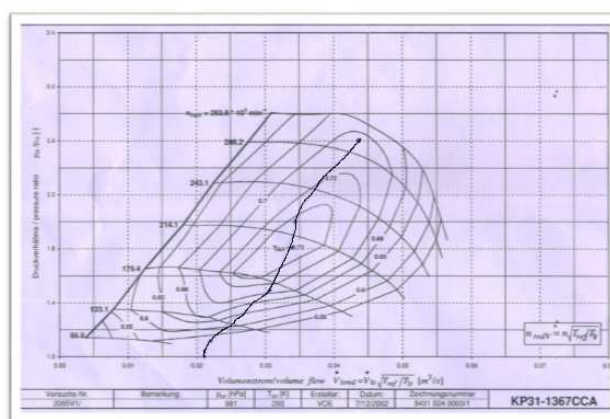


Figure 4: Compressor Map

Turbine Mapping

The Turbine Mapping is carried for the 1367(compressor) values as shown in table 7. Considering for KP35 Turbine. work of turbine (WT) is calculated by using the relation Work of compressor (WC) = work of turbine (WT) and is shown in table 8

Table 8: Turbine Values for KP35

Considering KP35 Turbine				
Turbine Efficiency	EGR %	P3/P4	P3	Mp
62%	20%	2.45	2.51	0.63
62%	20%	1.90	1.95	0.61
60%	18%	1.75	1.80	0.58
57%	12%	1.37	1.40	0.49
55%	5%	1.26	1.29	0.42

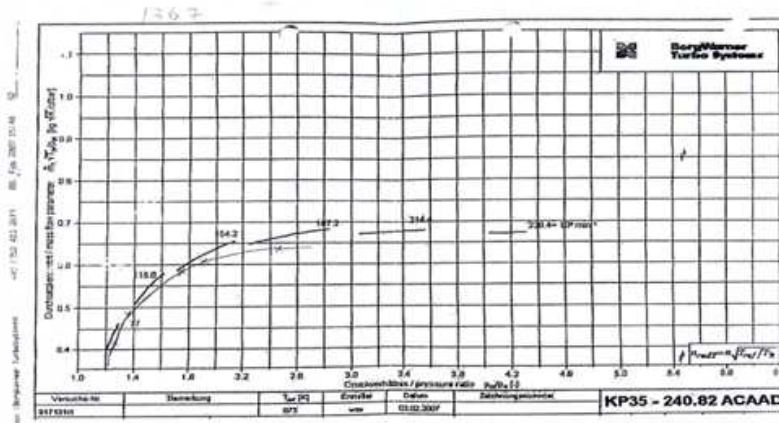


Figure 5: Turbine Map

Turbine Values TR43

The Turbine Mapping is carried for the 1367(compressor) values as shown in table 7. Considering for KP43 Turbine. work of turbine (WT) is calculated and plotted in table 9

Table 9: Turbine Values TR43

Considering TR43 Turbine				
Turbine Efficiency	EGR %	P3/P4	P3	Mp
62%	20%	2.45	2.51	0.63
62%	20%	1.90	1.95	0.61
60%	18%	1.75	1.80	0.58
57%	12%	1.37	1.40	0.49
55%	5%	1.26	1.29	0.42



Along the three given maps, we have selected the compressor map¹³⁶⁷ which has required choke and surge line. The other two maps were rejected due to the surging and choking.

Turbine Mapping

In turbine, we took two types of turbine maps (i.e. KP35 & TR43) for each compressor in all possible combination. Finally, we came through plotting that KP35 is matching with compressor 1367. The other compressor isn't matching with the turbine maps. We successfully concluded our project by matching the compressor 1367 to the turbine KP35.

REFERENCES

1. Shingne, P., Assanis, D., Babajimopoulos, A., Keller, P. et al., "Turbocharger Matching for a 4-Cylinder Gasoline HCCI Engine Using a 1D Engine Simulation," SAE Technical Paper 2010-01-2143, 2010, <https://doi.org/10.4271/2010-01-2143>.
2. Leufven, O. and Eriksson, L., "Engine Test Bench Turbo Mapping," SAE Technical Paper 2010-01-1232, 2010, <https://doi.org/10.4271/2010-01-1232>.
3. Tyagi, N., gupta, S., Bhardwaj, P., Gayen, H. et al., "Optimization of GENSET Engine for CPCB- II Norms using Cost Effective Techniques," SAE Technical Paper 2013-01-2838, 2013, <https://doi.org/10.4271/2013-01-2838>.
4. Wang, Y. and Gangopadhyay, A., "Exhaust Backpressure Estimation for an Internal Combustion Engine with a Variable Geometry Turbo Charger," SAE Technical Paper 2009-01-0732, 2009, <https://doi.org/10.4271/2009-01-0732>.
5. Stoffels, H., Quiring, S., and Pinggen, B., "Analysis of Transient Operation of Turbo Charged Engines," SAE Int. J. Engines 3(2):438-447, 2010, <https://doi.org/10.4271/2010-32-0005>.
6. Kapoor, P., Costall, A., Sakellaris, N., Hooijer, J. et al., "Adaptive Turbo Matching: Radial Turbine Design Optimization through 1D Engine Simulations with Meanline Model in-the-Loop," SAE Technical Paper 2018-01-0974, 2018, <https://doi.org/10.4271/2018-01-0974>.
7. Mutta, S., Sathiyarayanan, M., Gupta, P., Nandhakumar, K. et al., "Thermodynamic Study of Turbocharger Matching and Combustion Optimization for Better Low End Torque and High Speed Power," SAE Technical Paper 2016-28-0015, 2016, <https://doi.org/10.4271/2016-28-0015>.
8. Brynych, P., Macek, J., Tribotte, P., De Paola, G. et al., "System Optimization for a 2-Stroke Diesel Engine with a Turbo Super Configuration Supporting Fuel Economy Improvement of Next Generation Engines," SAE Technical Paper 2014-32-0011, 2014, <https://doi.org/10.4271/2014-32-0011>.
9. Brockbank, C., "Application of a Variable Drive to Supercharger & Turbo Compounder Applications," SAE Technical Paper 2009-01-1465, 2009, <https://doi.org/10.4271/2009-01-1465>.
10. Watel, E., Pagot, A., Pacaud, P., and Schmitt, J., "Matching and Evaluating Methods for Euro 6 and Efficient Two-stage Turbocharging Diesel Engine," SAE Technical Paper 2010-01-1229, 2010, <https://doi.org/10.4271/2010-01-1229>.
11. Ismail, M., Costall, A., Martinez-Botas, R., and Rajoo, S., "Turbocharger Matching Method for Reducing Residual Concentration in a Turbocharged Gasoline Engine," SAE Technical Paper 2015-01-1278, 2015, <https://doi.org/10.4271/2015-01-1278>.
12. Shamsderakhshan, M. and Kharazmi, S., "Turbocharger Matching and Assessments of Turbocharger Effect on a Diesel Engine based on One-Dimensional Simulation," SAE Technical Paper 2014-01-2557, 2014, <https://doi.org/10.4271/2014-01-2557>.
13. Zinner, C., Stelzl, R., Schmidt, S., Leiber, S. et al., "Experimental Verification and Drivability Investigations of a Turbo Charged 2-Cylinder Motorcycle Engine," SAE Technical Paper 2014-32-0112, 2014, <https://doi.org/10.4271/2014-32-0112>.